Mike Hesch
K6TNA

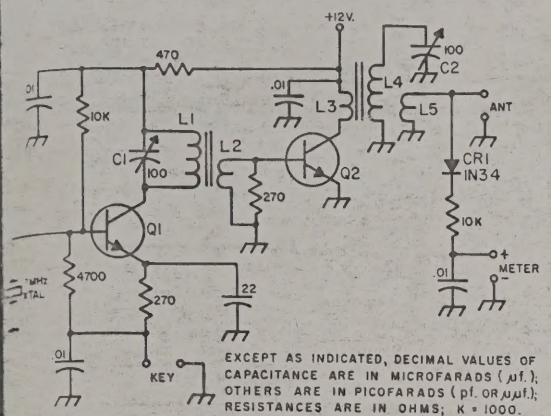


Fig. 10-39 — Circuit diagram of the 21-MHz "Milligallon." Fixed resistors are composition, 1/2 watt or smaller. Fixed capacitors are ceramic.
C1, C2 — 7- to 100-pF midget compression mica trimmer (Elmenco 423).
L1 — App. 2.5-μH; 23 turns No. 26 on ferrite toroid form (Amidon T-50-6, 0.5-inch OD; see also footnote 1).
L2 — 4 turns No. 26 on same form as L1.
L3 — 4 turns No. 22 on same type form as L1.
L4 — App. 0.8-μH; 13 turns No. 26 on same form as L2.
L5 — 3 turns No. 22 on same form as L3.
Q1, Q2 — 2N3641 (Fairchild) or equivalent.

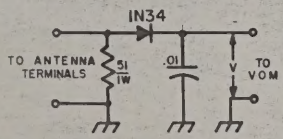


Fig. 10-40 — Dummy load and peak rectifier for measuring power output. The fixed capacitor is ceramic.

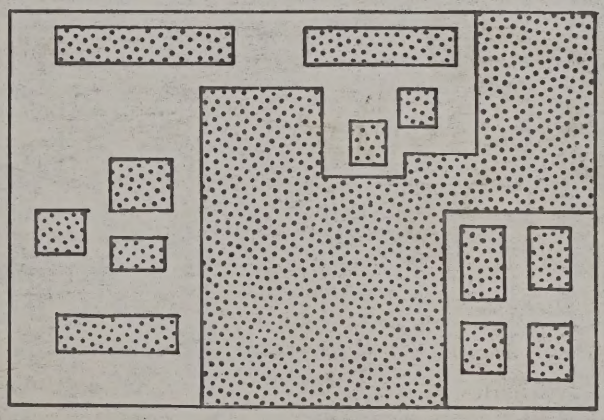


Fig. 10-41 — Circuit board layout (bottom view), full size. Shaded area is copper; white area is etched out.

excessive the builder should consider an antenna tuner such as the T network described by Johnson.[2] Capacitor C2 should be repeaked when the antenna system is connected.

Since the total current drawn by the transmitter is about 100 mA, power may be economically supplied by a 12-volt lantern battery.

The results obtainable with the milligallon will amaze all but the seasoned QRPer. In one month of operation, contacts were made all over the U.S. and Canada and with several stations in Japan. The antenna was a trap vertical.

[2] Johnson, "Band-Switching Transmatches," *QST*, October, 1967.

THE MK-II FM RECEIVER FOR 146 MHz

The simple receiver described here provides true fm reception. It uses a two-stage limiter and discriminator, a crystal-controlled converter for good stability, and a vernier drive for smooth tuning. Reception with the version shown is excellent. Selectivity is adequate for separating three local repeater output signals which fall at 146.79, 146.88 and 146.94 MHz. Sensitivity is such that a 0.2-μV signal with 5-kHz deviation is plainly audible. A 0.7-μV signal provides 20 dB of quieting. Limiting action is good on all but the weakest of signals.

Circuit Features

A block diagram of the MK-II is shown in Fig. 10-43. Two options are offered – FL1 for reducing images and cross modulation from nearby commer-

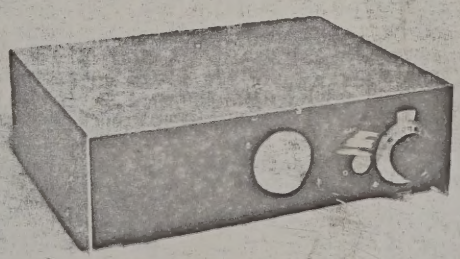


Fig. 10-42 — Front view of the completed 2-meter fm receiver.

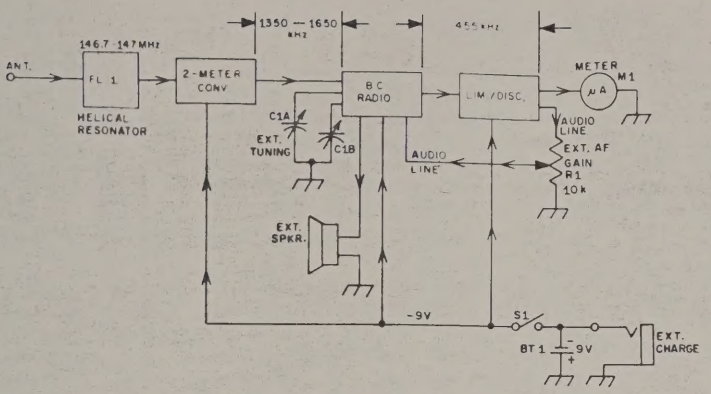


Fig. 10-43 — Block diagram of the assembled MK-II fm receiver. BT1 should be a large-size 9-volt battery, or 7 or 8 penlite cells connected in series.

C1 — Two-gang miniature variable, one section 40 pF and the other having 20 pF. See text. (J. W. Miller No. 1640 three-section unit used here, two gangs being connected in parallel.)

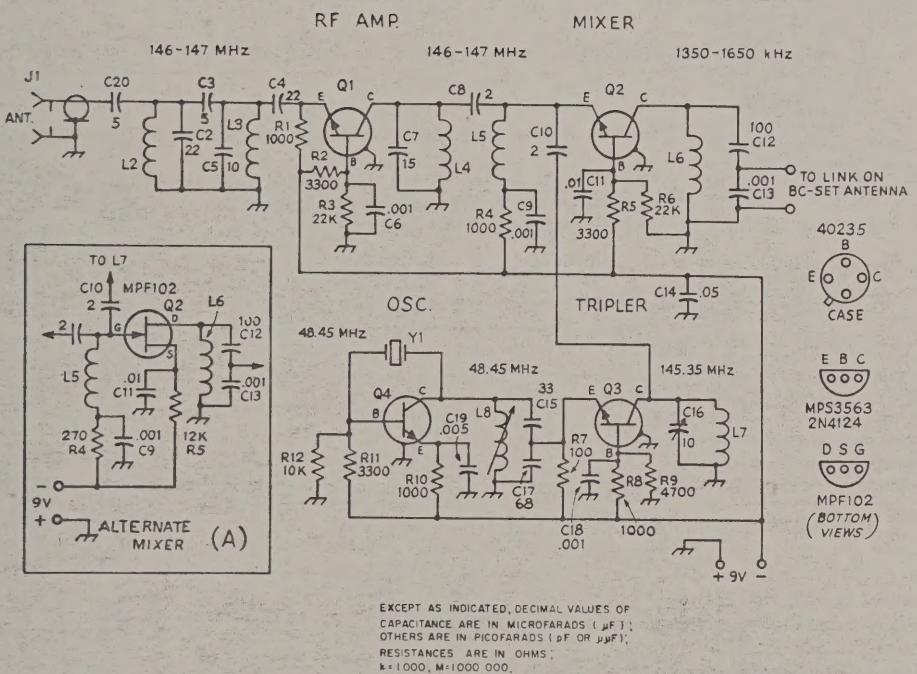


Fig. 10-44 — Circuit of the 2-meter converter. Parts not listed below are designated for pc-board layout purposes. Drawing A is discussed in the text. Fixed-value capacitors are disk ceramic. Resistors are 1/4- or 1/2-watt carbon.

C16 — 10-pF piston trimmer. Ceramic or pc-board air trimmer can be substituted.

J1 — SO-239-style chassis fitting.

L1 — Not used.

L2 — 3 turns No. 20 enam. wire, 3/16-inch ID, 1/8-inch long.

L3 — 4 turns No. 20 enam. wire, 3/16-inch ID, 5/16-inch long.

L4 — 5 turns No. 20 enam. wire, 3/16-inch ID, 5/16-inch long.

L5 — 15 turns No. 20 enam. wire, 3/16-inch ID, closewound.

L6 — 100-μH rf choke (Millen J302-100 or J. W. Miller 70F104AI suitable). *Must be 100 μH in value.*

L7 — 5 turns No. 16 tinned copper wire, 1/4-inch ID, 3/8-inch long.

L8 — 10 turns No. 26 enam. wire, closewound on 1/4-inch dia slug-tuned form (J. W. Miller 4500-2 blank suitable). Variable inductance 0.35 to 0.6 μH required.

Q1-Q4, incl. — Npn bipolar transistor, RCA 40235 or 40637, Motorola 2N4124 or MPS3563 suitable, or any high-beta npn with f_T of 250 MHz or greater. (Q2 of inset A is Motorola MPF102, 2N5484, or HEP802.)

Y1 — 48.45-MHz 3rd-overtone crystal (International Crystal Co. type GP in FM-2 holder).

cial services, and M1, a zero-center tuning meter. The jack labeled EXTERNAL CHARGE should be included only if a nickel-cadmium battery is used.

Fig. 10-44 illustrates the converter circuit. Inset drawing A shows how the mixer can be changed to a JFET. The modification was tried in the receiver. It reduced cross-modulation effects caused by a nearby commercial repeater. Since the MPF102 is an N-channel device it will be necessary to employ the hookup shown (gate returned to the minus bus, and drain returned to chassis ground through L6). The values of resistors R4 and R5 will have to be changed as indicated. R6 will be deleted if the JFET is used. No other changes are required. Though it was not tried, a common-gate JFET rf amplifier might work nicely at Q1, but with reduced gain over the bipolar amplifier shown.

Those wishing to use the bipolar arrangement for all four stages of the converter, but with a negative ground system (such as mobile), can simply substitute pnp transistors for Q1 through Q4. The Motorola 2N4126 would be suitable for this purpose. The positive-ground approach was adopted here to make the two additional circuit boards compatible with the bc receiver, which has a positive-ground hookup. (The foregoing technique applies only to the use of the converter in combination with the car radio, and not with the remainder of the circuits described here.

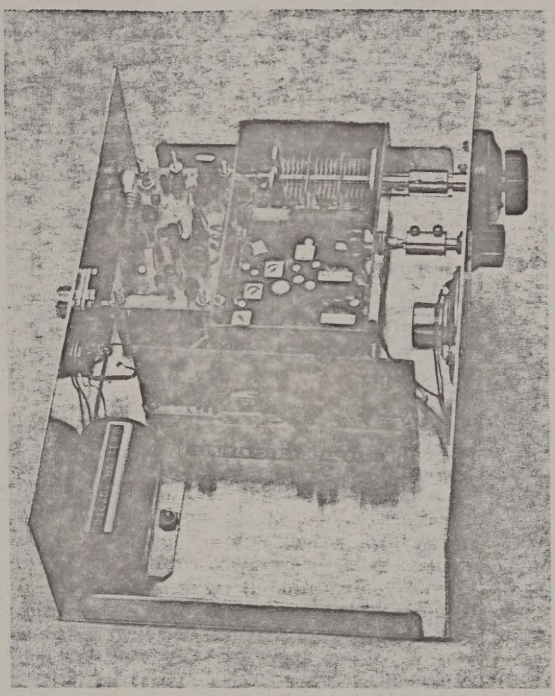


Fig. 10-45 — Inside view of the Pip-Squawk MK-II. The vacant area at the bottom has been reserved for a small transmitter and modulator. The limiter/discriminator board is mounted vertically by means of an L bracket. Four metal posts support the 2-meter converter at the upper left. The bc radio and its new tuning capacitor and gain control are housed in the shield compartment at the upper center. An aluminum cover is used to enclose the shield box during operation.

BC-Set Modifications

A 6-turn link of small-diameter hookup wire must be wound over the low-impedance end of the built-in ferrite-bar antenna of the bc set. This will connect to the i-f output of the converter by means of twisted wire or shielded conductor. The two-section tuning capacitor should be set at the high end of the bc band (1650 kHz or higher), then glued in position. Alternatively, it can be removed and discarded. A two-gang bandspread capacitor of approximately 20-pF maximum capacitance (oscillator section), and 40 pF in capacitance (maximum) for the mixer section is wired in parallel with the tuning capacitor in the set. A three-section J. W. Miller component was used in the writer's model. Each section is 20-pF maximum capacitance, so two of the gangs are wired in parallel to provide 40 pF for the mixer tuning. A two-section broadcast variable can be used by removing the proper number of plates to secure the desired bandspread. Other styles of two-gang variables can be modified in a like manner.

Fig. 10-46 shows the typical configuration used at the second i-f amplifier and detector of most imported pocket-size bc sets. After locating the detector diode, CR1, the modifications shown can be made. Remove all components between the letters A and B. Audio gain control R2 can be replaced by a panel-mount type of the same value (with switch), or the ingenious builder can retain the original part and mount it on the front panel of the MK-II. Terminals A and B will connect to the limiter/detector board of Fig. 10-47.

The speaker from the bc radio is mounted on the front panel of the MK-II. In fact, the speaker grille from the bc set was pried off the plastic case and used between the speaker and the front panel in true miserly fashion. Some sets do not have separate grilles, so perforated metal or circuit board can be used to protect the speaker cone.

Limiter/Discriminator

The circuit of Fig. 10-47 shows that two bipolar transistors are used in an RC-coupled limiter strip, followed by a diode discriminator. RFC1 and RFC2 are used to prevent vhf parasitics. Two Amidon ferrite beads are used for each choke. Alternatively, a 22-ohm 1/2-watt resistor can be substituted for each choke. It can be seen that here, again, the npn transistors are connected in the circuit for a *positive* ground system. Type 2N4126 transistors can be substituted if one wishes to use this assembly with receivers that have a negative ground.

Diodes CR1 and CR2 function in a self-adjusting limiter arrangement. They can be omitted if the bc set used ahead of the limiter board is low

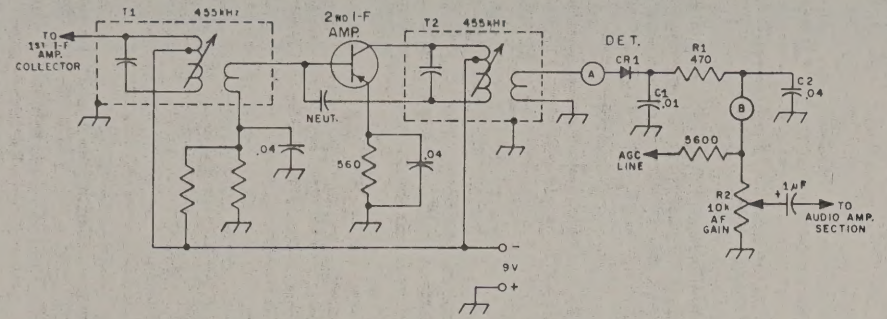


Fig. 10-46 — Typical circuit of second i-f amplifier and a-m detector of imported bc-band radios. Points marked A and B indicate where circuit is opened for addition of the limiter/discriminator. Components between points A and B are discarded. R2 is replaced by a panel-accessible gain control (see text). Values for R1, C1 and C2 are not necessarily the same in all imported sets.

Fig. 10-47 — Schematic diagram of the limiter/discriminator. Capacitors are disk ceramic. Larger values are low-voltage types. Resistors are 1/4- or 1/2-watt carbon. Parts not listed below are numbered for pc-board layout.

CR1, CR2 — 1N34A germanium diode.

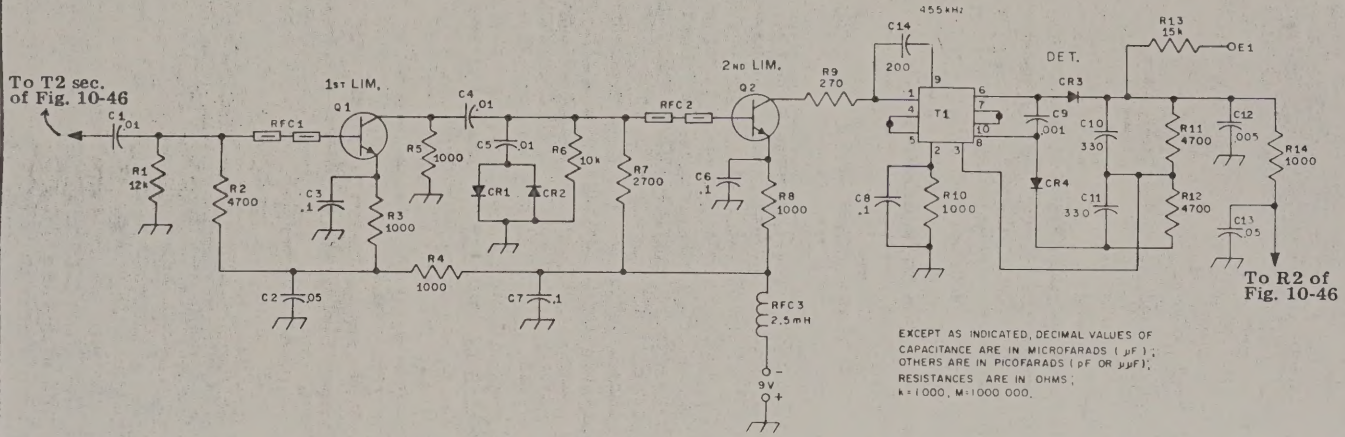
CR3, CR4 — Matched set of germanium diodes (Sylvania 1N35 matched pair available from Allied Electronics. Also, see text).

Q1, Q2 — RCA 40235 or 40637. Motorola 2N4124 suitable.

RFC1, RFC2 — Two Amidon ferrite beads (see text).

RFC3 — 2.5-mH choke (James Millen J302-2500 miniature or equiv.).

T1 — 455-kHz discriminator transformer (J. W. Miller 8806).



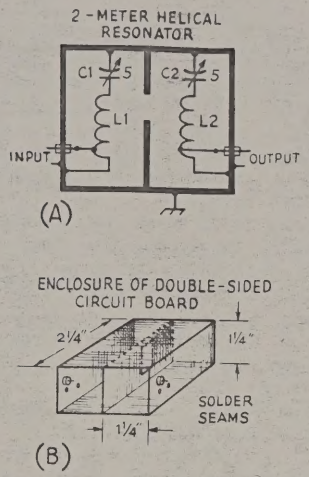


Fig. 10-48 — Circuit of the helical resonator. Double-sided pc board is used for the box walls, and is soldered along each seam by means of a pencil-type iron. E. F. Johnson silver-plated air-variable capacitors (No. 189-563) were used in this model, but high-dielectric piston trimmers can be substituted. Coils L1 and L2 consist of 4 1/2 turns of No. 12 copper wire, 3/4 inch in diameter, and 3/4 inch long. Each coil is centered in its compartment and tapped 1/4 turn from ground to obtain a bilateral 50-ohm impedance. A 3/8 X 5/8-inch aperature is cut in the center divider, and is opposite the second and third turns of each coil. C1 and C2 are tuned for peak signal response with the resonator connected between the receiver input and the feed line. The bottom end of the assembly need not be enclosed. Ideally, the enclosure should have no soldered seams, and both it and the coils should be silver plated. This suggests the use of large-diameter copper tubing for the outer shield if maximum Q is desired.

in i-f gain. Matched diodes should be used at CR3 and CR4. Those having an assortment of germanium diodes can select two that have nearly equal dc resistance readings (when checked with an ohmmeter). Match them in resistance in both the forward (low dc resistance) and reverse (high dc resistance) directions.

Terminal E1 of Fig. 10-47 provides a test voltage (dc) for aligning the discriminator. After alignment, those wishing to can connect a zero-center microammeter between E1 and ground for use as a tuning meter. Lafayette Radio sells a low-cost miniature meter for this purpose.

Assembling the MK-II

The photographs show that the MK-II is not a miniature unit. The writer likes to allow plenty of extra space in his projects, and this assembly is surely a case in point. A large portion of the cabinet has been reserved for a 2-watt fm transmitter. However, the builder can certainly shrink the 10 1/2 X 8 X 3-inch dimensions by a considerable margin if he is skilled at packing many parts into a small space. This enclosure is fashioned from 1/16-inch-thick aluminum stock. The panel is painted dark green.

To reduce unwanted pickup of bc stations, the pocket radio is enclosed in a box made from double-sided pc board. A press-fit U-shaped aluminum lid encloses the top of the compartment. The bandspread tuning capacitor and gain control are contained in the same box. No. 6 spade bolts hold the assembly to the main chassis.

Tune-up and Use

It is suggested that the builder test the bc set independently after it is modified and mounted in its shield box. The components which were removed between points A and B of Fig. 10-46 can be clipped between those points for the test. Connect a 9-volt battery and tune in a bc station. Make certain that the new volume control and tuning capacitor are functioning as intended. Adjust the trimmers on the tuning capacitor to assure tracking of the mixer and oscillator sections of the radio. Next, connect a signal generator to the base of the mixer through a 10-pF blocking capacitor. Set the generator for 455-kHz output and align the i-f transformers for peak response at that frequency.

The next step is to connect the limiter/discriminator board to the circuit in place of the components temporarily connected between points A and B. Attach a VTVM or zero-center μA meter between E1 and ground (Fig. 10-47). If a VTVM is used, set it for the 1.5-volt scale and adjust the meter-set control so that the needle is exactly on zero. Now, apply a strong signal (several hundred μV) to the mixer input, using 1500 kHz as a test frequency. Vary the signal generator plus and minus 15 kHz while observing the meter. The signal should swing plus and minus in a linear fashion. (If a VTVM is used for the test, it will be necessary to switch the polarity back and forth

Fig. 10-49 — View of the homemade helical resonator shown in Fig. 14-66. Double-sided pc board is used for all walls but the top one in this version. Flashing copper was used for the top surface in this model, but pc board would have been suitable.

with the meter reversing switch.) The meter should return to zero when no signal is present. If the foregoing conditions are not met it will be necessary to adjust T1 of Fig. 10-47 for a linear response. The alignment of T1 will be a tedious task, so plan to spend some time in the adjustment process. Alternately tweak the pink and blue cores of the transformer, a few degrees of rotation each time, then sweep across the 30-kHz range and observe the meter response. Try various settings of the cores until proper alignment is achieved. If a signal generator is not available, tune across a *strong* bc station and adjust T1 for linear response of the discriminator. After T1 is correctly adjusted, there should be no a-m detection of the bc signal when the station is tuned in to its center frequency. Readable audio will be heard, however, when tuning to either side of center frequency.

Install the bc set and the limiter/discriminator assembly in the chassis. Next, connect the 2-meter converter to the circuit. Tune in a weak 2-meter fm signal, or use the output from a vhf signal generator. Adjust L8 and C16 of Fig. 10-44 for maximum signal response at 146.8 MHz. Spread or compress the turns of L2, L3 and L4 for peak response. Use an insulated rod while making these tests. This completes the adjustments. The converter can now be bolted in place in the cabinet.

Since the MK-II represents one of the least sophisticated approaches to fm reception, some ills may become manifest. Strong signals from nearby two-way commercial services may show up in the tuning range of the receiver. Also, signals from the lower portion of the 2-meter band may appear as images. The helical-resonator filter shown in Fig. 10-48 can be built and used ahead of the receiver to reduce or eliminate unwanted responses. It is easy to assemble and is very inexpensive, yet is superior in performance to most strip-line filters. Design data for these filters are given in *ITT Reference Data for Radio Engineers*, 5th Edition, Chapter 22. The filter consists of two very high-*Q* tuned circuits, coupled through a small aperture in the metal wall between them. Input and output taps are set for a 50-ohm impedance.

AN FM TRANSMITTER FOR 2 METERS

Whether you're a would-be fm-er, or a person who has already explored the world of fm and repeaters, this little 2-watt solid-state transmitter can be the key to new operating enjoyment. No need to scoff at the QRP aspect of this project, because here we have a piece of gear that can be operated from the 12-volt automotive system, a dry-battery pack (10 size-D flashlight batteries in series, or a 12-volt lantern battery), or a simple ac-operated 12-volt dc supply. This feature makes possible a variety of amateur applications, and noteworthy among them, emergency/portable operation.

Rf Circuit

Four low-cost bipolar transistors are used in the circuit of Fig. 10-51. Q1 is the oscillator, which uses 18-MHz fundamental crystals ground for a load capacitance of 20 pF. Output from the first stage is taken at 73 MHz, a frequency multiplication of 4. The second stage, Q2, doubles the frequency to 146 MHz. The remaining stages operate as amplifiers at 146 MHz.

Frequency modulation is effected by applying audio to voltage-variable diode (Varicap) CR1. As the amplitude of the audio varies, the junction capacitance of CR1 changes, and this change pulls the crystal frequency above and below its preset frequency to provide fm. The amount of deviation, or swing, is determined by the audio level impressed across CR1. Normally, this will be set for 5- or 15-kHz deviation, depending upon the bandwidth in vogue for a given area. Approximately 1.5 volts of reverse bias is developed within the circuit and appears across CR1. This eliminates the need to provide back bias from the 12-volt line.

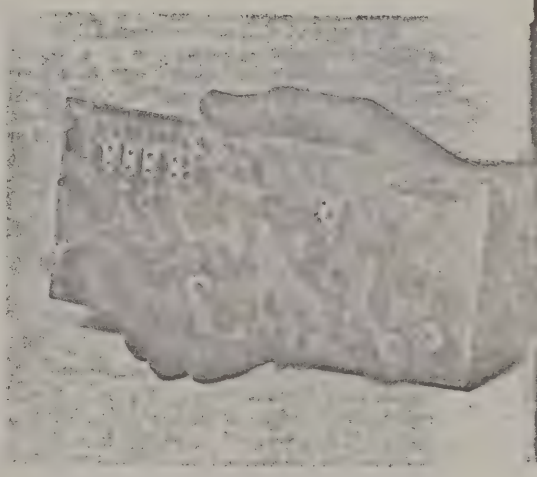


Fig. 10-50 — Top view of the rf module showing its relative size. The crystal sockets and Vector push-in terminals for connection to the crystal switch are at the upper left. The coils near the crystal sockets are for adjusting the crystals to frequency. The oscillator is at the lower left, and the PA stage is at the far right. The small loop of wire at the lower center is a B-plus jumper.

Crystals Y1 through Y4 are adjusted to the desired frequency by means of inductors L1 through L4. Approximately 1 kHz of shift is possible with the coil value given. If greater overall control of the frequency is desired, simply replace fixed-value capacitor C27 with an air trimmer of 30-pF maximum capacitance. Regulated voltage is supplied to Q1 (and to the bias line of Q2) by

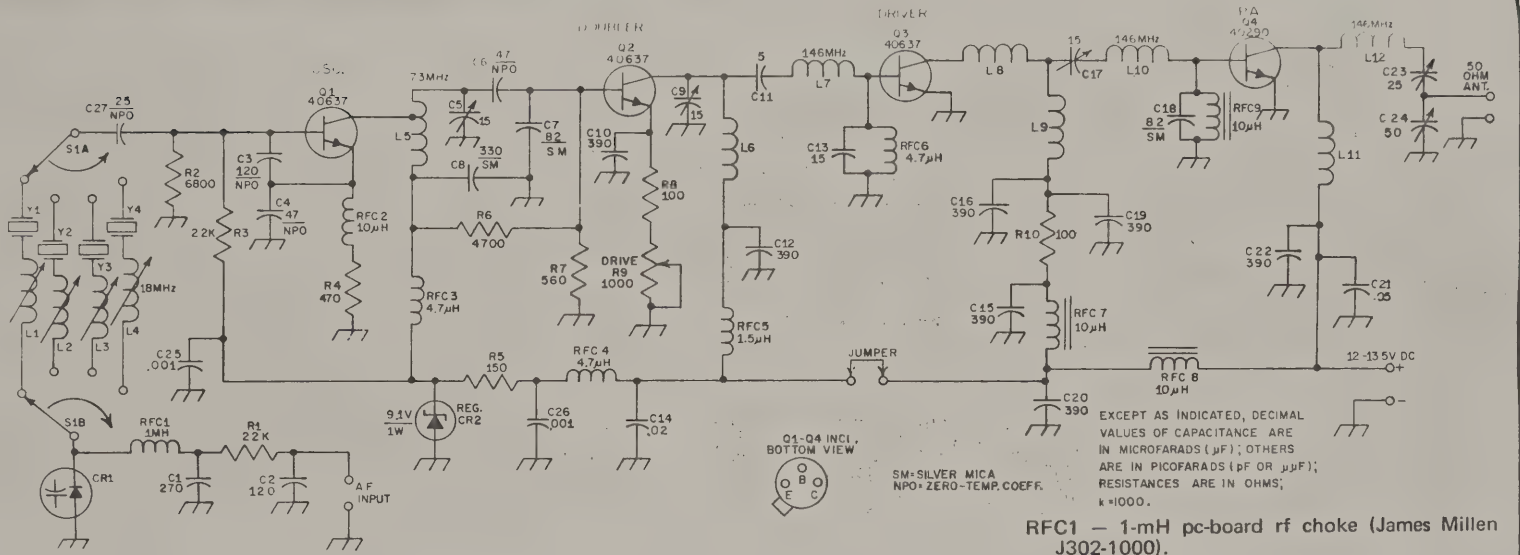


Fig. 10-51 — Schematic diagram of the rf section of the transmitter. Most of the parts are available from Allied Electronics (Catalog No. 710), Chicago, IL. Numbered components are not given in the parts list are so labeled for circuit-board identification. Fixed-value capacitors are disk ceramic unless noted differently. Fixed-value resistors are 1/2-watt carbon.

CR1 — Varicap diode, 82-pF nominal capacitance, 73.8 to 90.2 pF total range (Motorola MV839 or nearest equiv.).

CR2 — Zener regulator diode (Motorola HEP-104 or equivalent).

C5, C9, C17 — 1.7 to 14.1-pF pc-type air variable (Johnson 189-505-5). Compression trimmers or ceramic padders can be substituted.

C23, C24 — Phenolic-base ceramic padder (Erie type 557 or equiv.) Cut off pheonolic flange.

C3, C4, C6, C27 — NP0 disk (Sprague from Allied Electronics).

L1-L4, incl. — Pc-board variable inductor, 0.68-µH nominal (J. W. Miller 46A687CPC. J. W. Miller Co., 19070 Reyes Ave., Compton, CA 90221. Catalog available).

L5 — 5 turns No. 16 bus wire, 5/16-in ID X 5/8 in. long. Tap 1 1/2 turns from C5 end (0.11 µH).

L6, L10 — 3 turns No. 16 bus wire, 5/16-in. ID X 1/2 in. long (.075 µH).

L7, L8 — 6 turns No. 22 enam., close-wound, 3/16 in. dia See text.

L9 — 4 turns No. 22 enam., 3/16-in. dia., spaced to occupy 3/8 inch on form (.06 µH).

L11 — 12 turns No. 22 enam., close-wound, 3/16-in. dia (0.435 µH).

L12 — 5 turns No. 16 bus wire, 5/16-in ID X 1/2 in. long (0.14 µH).

Q1-Q4, incl. — RCA bipolar transistor. Substitutes should have equal or higher voltage, wattage and f_T ratings.

R9 — 1000-ohm linear-taper pc-board carbon control (IRC type X-201, R102B or equiv.).

RFC1 — 1-mH pc-board rf choke (James Millen J302-1000).

RFC2 — 10-µH molded rf choke (J. W. Miller 9310-36). See text.

RFC3, RFC4, RFC6 — 4.7-µH molded rf choke (J. W. Miller 9310-28). See text.

RFC5 — 1.5-µH molded rf choke (J. W. Miller 9310-16). See text.

RFC7-RFC9, incl. — 10-µH low-Q rf choke. 4 turns No. 30 enam. wound on Amidon miniature ferrite bead (Amidon Assoc., 12033 Otsego St., N. Hollywood, CA 91607).

S1 — 2-pole, 4-position nonshorting phenolic or ceramic rotary switch.

Y1-Y4, incl. — 18-MHz fundamental crystal cut for 20-pF load capacitance. International Crystal Co., .0025 percent commercial standard, FI-4 holder. High-accuracy .002-percent type preferred for best stability. FI-4 pc-board sockets used in this transmitter. Crystals from other manufacturers may work satisfactorily if ground for 20-pF load. (International Crystal Mfg., Inc., 10 North Lee, Oklahoma City, OK 73102.)

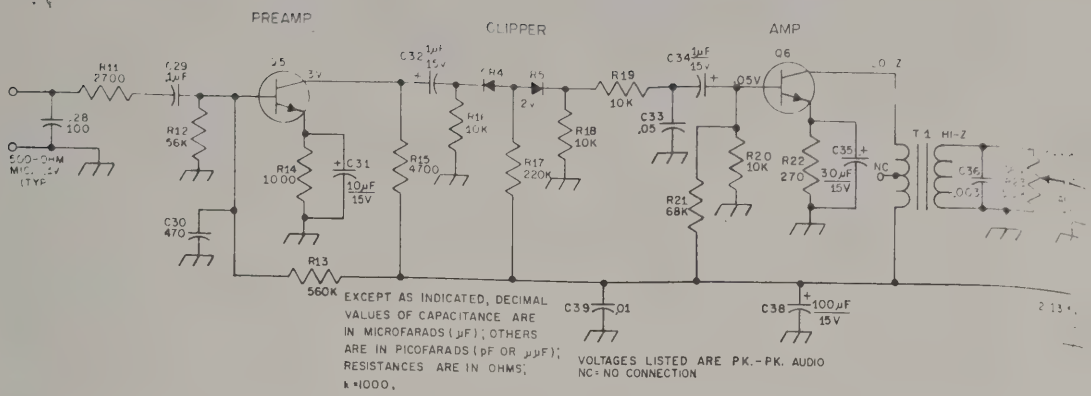


Fig. 10-52 — Schematic diagram of the clipper/modulator. Numbered components not listed below are for circuit-board identification. Capacitors are disk ceramic or paper. Polarized capacitors are electrolytic. Fixed-value resistors are 1/2-watt carbon.

CR4, CR5 — Silicon diode. 1N914 or top-hat rectifier suitable.

Q5, Q6 — Audio-type npn bipolar transistor. RCA 40231 or equiv. Also, Motorola 2N4123 or MPS-A10 suitable.

R11 — See text.

R23 — 50,000-ohm linear-taper carbon control. Pc-board type IRC X-201, R503B.

T1 — Miniature audio transformer, 10,000-ohm pri., 2000-ohm sec., c.t. not used. Radio Shack/Archer 273-1378 or equiv. Connect low-Z winding to Q6 collector.

means of Zener diode CR2. This measure helps insure against oscillator instability.

A drive control, R9, is connected in the emitter lead of Q2 to permit the operator to reduce power to the minimum amount needed. This measure helps to prolong the life of dry batteries during portable operation.

The Modulator

Only a few peak-to-peak volts of audio are needed to provide fm. A two-stage audio channel is shown in Fig. 10-52. This circuit amplifies the microphone output to a suitable level for clipping at diodes CR3 and CR4. A small amount of forward bias is used on the diodes to permit clipping action at relatively low audio level. The 10,000-ohm resistor and .05-µF capacitor used after the clipper diodes serve as a filter to reduce the harmonics caused during clipping. Output stage Q6 amplifies the clipped audio to a maximum level of 20 volts peak to peak. The deviation control, R23, is adjusted to provide the amount of frequency swing needed. A value of approximately 3 volts pk-pk is typical for 5-kHz deviation with the circuit of Fig. 10-51.

Construction Data

If you have built a commercial kit, you can assemble this transmitter easily. Circuit-board templates for the transmitter and modulator are available from ARRL for 50 cents and a *large* self-addressed, stamped envelope. A parts-placement overlay is included in the package.

Some of the inductors are wound on 1/4-inch diameter phenolic rod. Any low-loss rod material (Plexiglas or polystyrene) can be used, or, the coils can be wound on a 1/4-inch form, slipped off, and used as air-wound inductors. If this is done, put a drop of coil dope on each inductor to hold the turns in place. The large air-wound coils can be wound over a drill bit of appropriate size. Ferrite beads are used as cores for chokes RFC7, 8 and 9. Each choke has four turns of No. 30 enameled wire looped through its ferrite bead. The chokes, after being installed on the circuit board, are glued in place with china cement.

Glass-epoxy circuit board is recommended for the rf module. Low-cost phenolic board is suitable for the modulator. Poor-quality circuit board can cause problems in the rf module.

Heat sinks should be used on transistors Q3 and Q4. Small clip-on types are suitable. Wakefield Engineering Co. makes a wide variety of these devices. They are listed in most mail-order catalogs. Alternatively, homemade sinks can be made from 16-guage aluminum or brass stock.

The transmitter can be housed in any metal box that suits the builder's fancy. The transmitter board measures 3 X 7 1/2 inches. The modulator dimensions are 1 3/4 X 4 1/2 inches.

Tune-up

Connect the modulator output to the audio input terminals on the transmitter board. Use shielded audio cable or small-diameter coax. Attach a No. 47 pilot lamp across the transmitter output jack. This will serve as a visual-indicator dummy load of approximately 50-ohms impedance. Adjust the drive control to nearly full resistance (low power). Plug in a crystal and apply +12 volts to the B-plus terminal of the transmitter module (negative lead to ground foil). Couple a wavemeter to L5 and adjust C5 for a maximum reading at 73 MHz.

The next step is to set the wavemeter for 146 MHz and couple it to tank coil L6. Tune C9 for maximum output indication. The same technique

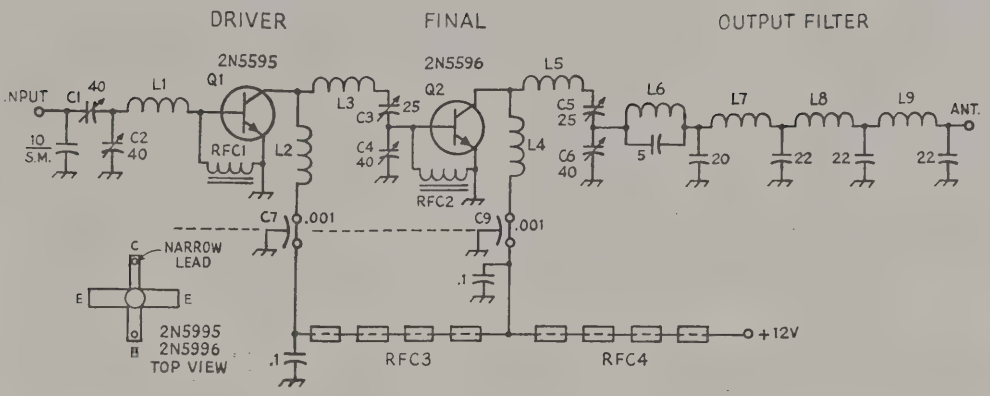


Fig. 10-53 — Schematic diagram of the 25-watt solid-state amplifier. Capacitors are disk ceramic unless otherwise noted.
C1, C2, C4, C6 — Compression trimmer.
C3, C5 — Air variable.
C7, C8 — Feedthrough type.
L1 — 1/4 X 2/3-inch copper strap.
L2, L4 — 9 turns No. 20 enam., closewound, 3/16-inch dia.
L3, L5 — 3 turns No. 14 tinned bus wire, 3/8-inch ID X 1/2-inch long.
L6 — 2 turns No. 20 enam., closewound, 1/4-inch dia.
L7-L9, incl. — 3 turns No. 20 enam., closewound, 1/4-inch dia.
Q1, Q2 — RCA power semiconductor, used with appropriate heat sink.
RFC1, RFC2 — 4 turns No. 30 enam. wound on a single ferrite bead (turns looped through the bead).
RFC3, RFC4 — Four ferrite beads on a 1/2-inch length of No. 20 wire.

is used to adjust the tuned circuits of Q3 and Q4. Now, advance the drive control to obtain maximum power. The dummy load should light at this point. Retune each stage for maximum lamp brilliance. Alternately adjust the tune and load trimmers, C23 and C24, for maximum glow of the lamp. Normal operation should cause the lamp to light to full brightness or slightly more. At 13.5 volts one should be able to obtain above-normal lamp brilliance. Couple a wavemeter to the output tank and check for second-harmonic energy. Choose a setting for C23 and C24 that provides maximum rf output at 146 MHz with the lowest possible reading at the second harmonic. The wavemeter response at 293 MHz should be very low, but some energy will be present.

Modulator Checkout

The circuit of Fig. 10-52 is designed for a low-impedance dynamic microphone (500 to 1000 ohms). If a high-impedance microphone is to be used, replace R11 with a 100,000-ohm unit. This will reduce the audio drive to Q5, thus preventing saturation of that stage. Also, the high-value resistor will give the high-impedance microphone a more suitable impedance to look into. Adjust R23 for the amount of deviation required. This can be done best by checking with another amateur who has an fm receiver of the desired bandwidth. The crystal can be rubbered to the desired frequency by adjusting its series inductor.

A final word of caution: *Never operate this transmitter into a highly-reactive load.* The SWR should be no higher than 2:1 to prevent damage to PA stage Q4. The output circuit of Q4 is designed to work into a 50- to 75-ohm load.

Suitable substitutes for Q1, Q2, and Q3 are 2N4427 and 2N3866. A new RCA device, the 2N5913, is recommended as a substitute for Q4. In fact, this type was tried in the circuit of Fig. 10-51 and performed superbly.

2-Meter Solid-State Amplifier

The circuit of Fig. 10-53 was developed for use with the new RCA 2N5995 and 2N5996 npn overlay rf power transistors. Both units are identical in appearance. Low-inductance radial-type leads are used for the base, emitter, and collector connections. The mounting stud is independent from the transistor elements. This ideal feature makes it possible to bolt the transistor to the wall of the equipment case, thus using the cabinet or chassis as a heat sink.

Both transistors are "mismatch tested" by the manufacturer. This means that an infinite load mismatch from short to open can be tolerated by the transistors during driven periods, provided the maximum junction temperature is not exceeded. The circuit shown here was tested for both short and open conditions, and no damage to the transistor resulted.

Driving power for the 2N5995 is 3/4 watt. The 2N5996 requires approximately 5-watts drive to develop its rated power output. The 2N5995 can be used as a driver for the 2N5996 to obtain approximately 20-watts output at 146 MHz. Similar circuit constants can be used for both stages.

A PORTABLE TRANSCEIVER FOR 144 MHz

Fig. 10-54 — The 2-meter transceiver is housed in a legal-bond box. A homemade dial-calibration chart for the receiver is pasted on the inside of the lid. Two plastic cable clamps serve as holders for the two-section 1/4-wavelength whip antenna (inside lid) when the unit is not in use. The antenna is held together at the center by a homemade 1/4-inch diameter threaded coupling.

Here's a vhf transceiver that's truly portable, is easy to build, and is capable of spanning many miles when used with a good antenna. It can be operated from its internal 12-volt flashlight-cell pack, from the cigar lighter of any 12-volt negative-ground car, or from an ac-operated 12-volt dc pack. The transmitter and the two-stage FET superregenerative receiver are assembled on etched circuit boards to simplify construction. The audio section is a prewired "import" – also on a circuit board. (From *QST*, August 1968.)

Receiver-Section Circuit

Two FETs are used in the simple receiver circuit of Fig. 10-56. A JFET (junction field-effect transistor), Q4, operates as a common-gate rf amplifier and offers a fair amount of detector isolation while providing a few decibels of gain. Its output is coupled to the detector, Q5, through C19, which is a "gimmick" capacitor. The latter consists of three turns of insulated hookup wire wrapped around the ground end of L8. The opposite end of the wire is soldered to the drain end of L7. A junction-type FET is used at Q4 to make it less subject to rf burnout than would be the case if an IGFET (insulated-gate FET) were used.

An IGFET is used as the detector, Q5. Since it is isolated from the antenna circuit there is little chance of its being harmed by strong rf fields.

Quench-frequency voltage is provided by R14 and C26 in the source lead of Q5. Feedback for the detector is between gate and source, making it necessary to keep the source above rf ground by means of RFC4.

Af output from the detector is taken from th drain through a quench-frequency filter consisting of C24, C25, RFC5 and C27. The filter prevent the quench voltage from reaching the audio amplifier. L9 isolates the af signal from the B-plu line, and R15 varies the drain-supply voltage t control superregeneration. R16 is the af gain control.

A word of caution at this point: When solderin the IGFET, Q5, into the circuit, be sure to conn a clip lead between the tip of the soldering iron and a good earth ground. This will help prevent damage to the gate of the 3N128 should stati charges be present. Also, *do not handle* the leads Q5. The leads should be removed from their shorting collar by means of a non-plastic or nonmetallic tool. A wooden toothpick is recommended for this, and for spreading the leads apart. Once Q5 is soldered in place, it should be quite safe from static-charge damage.

Transmitter Circuit

Referring again to Fig. 10-56, the transmitter section starts out with a Colpitts oscillator, Q1, which uses 72-MHz overtone crystals. C1 and the internal base-emitter capacitance of Q1 control the feedback. RFC1 keeps the emitter above rf ground. Bandpass coupling is used between Q1 and Q2 to reduce harmonics in the driving signal to Q2. A capacitive divider, C5 and C6, is used to match the collector of Q1 to the low base impedance of Q2. The high value of capacitance between the base of Q2 (C6) and ground helps to further reduce harmonic energy in that part of the circuit. Both Q1 and Q2 are low-cost Motorola transistors designed for amplifier or oscillator use at frequencies up to 500 MHz. They have a beta spread of 20 to 200, and have a collector-dissipation rating of 500 milliwatts. Other transistors can be substituted provided they have similar specifications. Resistors R5 and R6 establish Class A bias for Q2, making it easier to drive with the low output of Q1.

An RCA 2N3512 is used in the power amplifier, Q3. It was selected because of its low cost ($1.08) and high maximum dissipation rating of 4 watts. It is designed for high-speed switching applications and has an f_T of 375 MHz. Its h_{FE} rating is approximately 10. The low h_{FE} makes it easier to stabilize than would be the case if a high-beta transistor were used. Other transistors can also be used at Q3; a 40290, an HEP-75, and a 2N3553 were tried and performed as well as the 2N3512, but are more costly. To assure good heat dissipation at Q3, a heat sink is clipped to the transistor body. A Wakefield Engineering NF205 costs 27 cents and is ideal.

A capacitive divider, C10 and C11, matches the output of Q2 to the base of Q3. C10 tunes L3 to resonance. Forward bias is used on the base of Q3 to establish Class AB conditions. This provided greater output from Q3 than resulted with Class-C

Fig. 10-55 — Top-chassis layout of the transceiver. The receiver section is at the left. Controls for regeneration and modulation are in the foreground near the center of the chassis. The audio module is at the lower right, and the transmitter board is near the panel, directly under the loudspeaker. The home-made heat sinks are visible at the left end of the audio board.

operation, as is usually the case when the driver stage has low output. The collector tank of Q3 is a combination *L* and pi network. The *L* network, C12 and L4, matches the load to the collector. The pi network is used for harmonic reduction, a necessary provision when clean output is desired from transistorized transmitters. C12 tunes the PA tank to resonance; C15 serves as a loading control.

In order to assure suitable stability, the power leads of the stages are decoupled by means of C3, C9 and C14 in combination with R4, R8 and R11. The three resistors also serve as current-limiting devices to protect Q1, Q2 and Q3.

The Audio Section

The audio channel, AR1, can be purchased for approximately $8.00. It has a 200-milliwatt output rating at 9 volts, but by increasing the operating voltage to 12, and adding heat sinks to the two output transistors, slightly more than 300 milliwatts of output are available. This was done in the circuit of Fig. 10-36.

AR1 has two input impedances – 50 ohms and 100,000 ohms. Two output impedances are available, providing a 500-ohm transformer winding for modulator service, and an 8-ohm winding for driving a loudspeaker. The high-impedance input connects to the microphone gain control, R17, during transmit, and is switched to the receiver gain control, R16, during receive. The 50-ohm tap is not used.

Because the module is designed for a positive-ground bus (pnp transistors are used), it is necessary to "float" the entire assembly above chassis ground to prevent short-circuiting the power supply. Information on the mounting techniques and some modifications to the board are given later.

Building the Transceiver

The packaging of this circuit can be up to the builder. In this instance a standard legal-bond box was chosen. It measures 5 X 6 X 11 1/2 inches.

The chassis and panel are made from 16-gauge aluminum sheeting. An aluminum cookie tin from a hardware store can be the source of the panel and chassis stock. Many are made of heavy-gauge material and are large enough to assure that there will be excess stock. The chassis measures 11 1/4 X 4 X 1 inch. The panel is 11 1/4 inches by 4 3/4 inches. After the panel holes are drilled, a coating of zinc chromate should be sprayed on it. Then, after thorough drying, a coat of spray-can enamel or lacquer can be added for the final touch. The zinc chromate helps the finish coat of paint adhere to the aluminum sheeting.

The receiver and transmitter are built on etched circuit boards, but point-to-point wiring could be used if done neatly and with short connections. Etched-circuit templates are available from the ARRL if desired.[1] They are to scale and show where the various parts are mounted.

AR1 is insulated from the main chassis to prevent short-circuiting the power supply. It has a plus-ground bus; the rest of the transceiver circuit uses a negative ground. A piece of cardboard is mounted between the circuit board and the chassis to prevent accidental contact between AR1 and the chassis. AR1 is bolted to the chassis at four points. The four mounting holes in the main chassis contain small rubber grommets, each serving as an insulator. Terminals 1 and 9 of the audio board are common to its plus-ground bus. These terminals must be disconnected from the ground bus by removing the thin copper connecting strip which joins the circuits. A pocket knife works nicely for this job; the copper can then be peeled off.

To operate AR1 at 12 volts it is necessary to add heat sinks to the two transistors nearest the output transformer. The sinks can be fashioned from pieces of thin brass, copper, or aluminum. They are 1 1/2 inches long and each is formed by

[1] Scale circuit-board templates and parts placement guide are available from ARRL for 25 cents and an s.a.s.e.

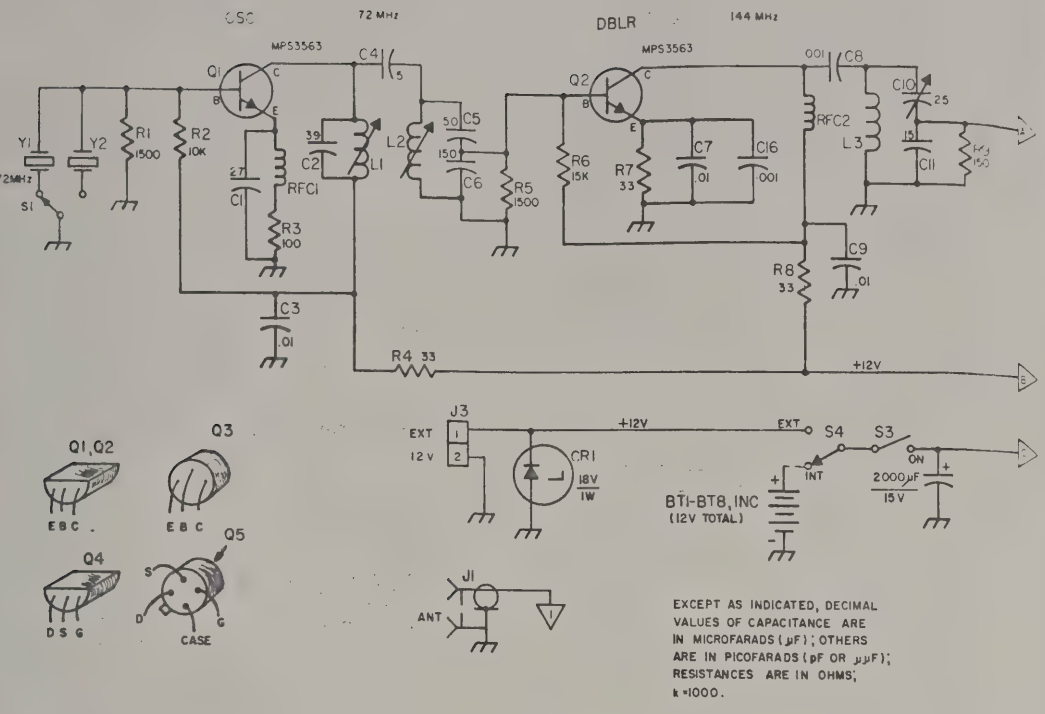


Fig. 10-56 — Schematic of the 2-meter transceiver. Fixed-value capacitors are disk ceramic except those with polarity marking, which are electrolytic. Resistors are 1/2-watt composition. Component numbering is for identification of parts on the circuit-board templates. Significant parts are listed below in the usual manner.

AR1 — 200-milliwatt audio module (Round Hill Associates Model AA-100*).

BT1-BT8, incl. — Eight 1.5-volt size-D flashlight cells, series-connected and mounted inside box by means of four Keystone No. 176 dual-battery clips.

C10, C12 — 5- to 25-pF ceramic trimmer (Erie 822-CN or equiv). (Midget 3- to 30-pF mica trimmer also suitable.)

C15 — 8- to 50-pF ceramic trimmer (Erie 822-AN or equiv). (Midget 8- to 60-pF mica trimmer also suitable.)

C19 — Gimmick-type capacitor. See text.

C20 — 15-pF subminiature variable (E. F. Johnson 160-107).

C22 — 5-pF min. variable (Hammarlund MAPC-15B, all but one rotor and one stator plate removed).

CR1 — 18-volt 1-watt Zener diode (used for transient protection during mobile operation).

J1 — SO-239 coax fitting (chassis mount).

J2, J3 — Two-terminal single-contact audio connector (Amphenol 75PC1M or similar).

L1, L2 — 3 turns No. 22 enam. wire spaced to occupy 1/2 inch on 1/4-inch dia ceramic slug-tuned form (J. W. Miller 4500-4*).

L3 — 4 turns No. 20 bare wire, 1/2 inch long, 5/16 inch ID.

L4 — 6 turns No. 20 bare wire, 1/2 inch long 5/16 inch ID.

L5 — Same as L3.

L6 — 8 turns No. 20 bare wire, 1 inch long, 5/16 inch ID. Tap 5 turns from source lead of Q4.

L7 — 5 turns No. 22 enam. wire, close-wound on 1/4-inch dia ceramic slug-tuned form (J. W. Miller 45005).

L8 — 4 turns No. 10 bare copper wire, 1 inch long, 3/8-inch ID. (The tap shown is not a physical one; see text discussion of C19.)

L9 — Total primary winding of 500-ohm ct transistor output transformer. The 8-ohm secondary winding not used. (Argonne AR-164 or similar.)

R15-R17, incl. — 100,000-ohm audio-taper carbon control.

RFC1 — Miniature 50-μH choke (Millen 34300-50*).

RFC2-RFC4, incl. — Miniature 2.7-μH rf choke (Millen 34300-2.7).

RFC5 — Subminiature 10-mH rf choke (J. W. Miller 73F102AF).

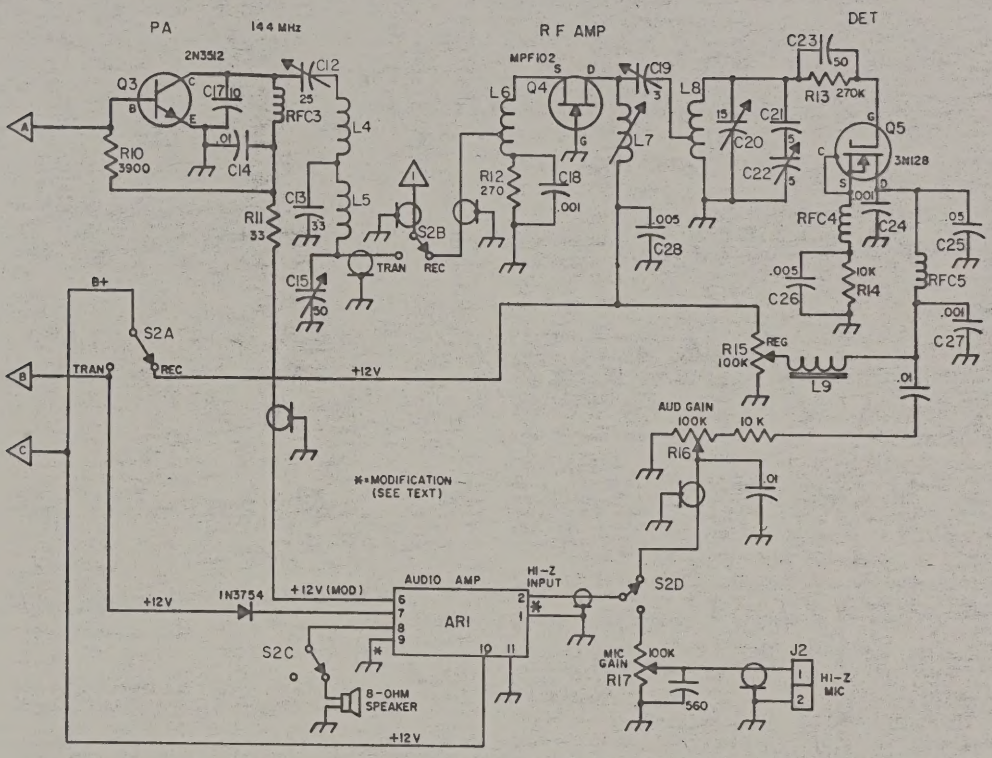
S1, S4 — Spdt slide switch.

S2 — 4-pole 2-position phenolic single-section rotary wafer switch. (Mallory 3142J.)

S3 — Spst slide switch.

Y1, Y2 — 72-MHz overtone crystal (International Crystal Co. in HC-6/U holder*).

* Round Hill Assoc., Inc., 434 Sixth Ave., NY, NY 10011.
* J. W. Miller Co., 19070 Reyes Ave., Compton, CA 90221.
* International Crystal Co., 10 N. Lee St., Oklahoma City, OK 73102.
* James Millen Mfg. Co., 150 Exchange St., Malden, MA 02148.



warping the stock around a drill bit which is slightly smaller in diameter than the body of the transistor.

All interconnecting rf leads are made with subminiature coax cable, RG-174/U (Belden 8216). Shielded audio cable should be used for all af wiring which is more than a couple of inches in length. A bargain-house import is used for the receiver tuning dial. No slippage was noted with the 2-inch-diameter model used here. The next smaller model is not recommended because it will not handle the torque of the tuning capacitor.

A 2 1/2-inch-diameter loudspeaker is used. Its protective grille can be made from perforated aluminum.

Two 3-inch-long brass angle brackets, each with 3/4-inch sides, are used as mounts for the panel-chassis assembly inside the box. Two 6-32 nuts are soldered to the bottom side of each bracket, directly under No. 10 access holes. Four

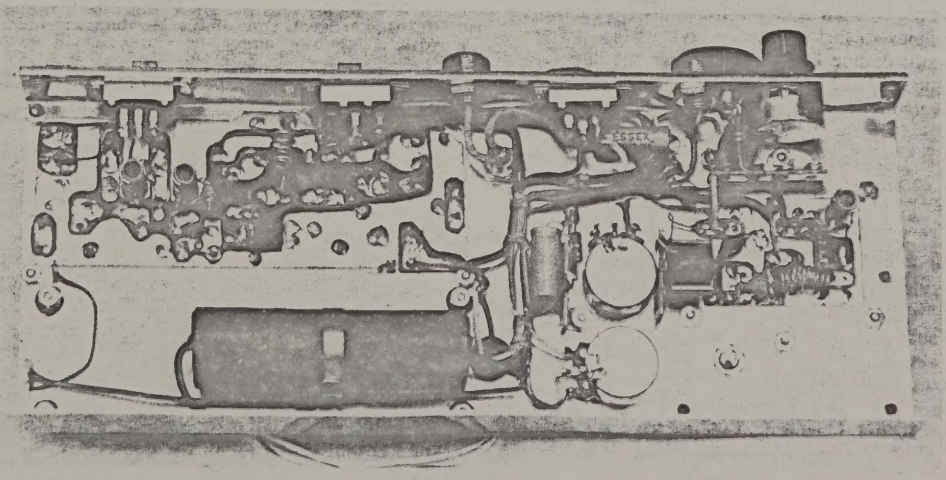


Fig. 10-57 — Bottom view of the chassis. The receiver board is at the right. The transmitter board is at the upper left. A 2000-μF 15-volt electrolytic is mounted near the rear lip of the chassis.

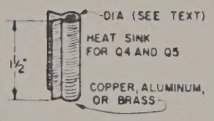


Fig. 10-58 — Details of the homemade heat sinks for AR1.

6-32 X 3/8-inch screws hold the transceiver in place. The brackets are attached to the sides of the box with 4-40 hardware.

Tune-Up and Use

The receiver should be tested first. With an antenna connected to J1, apply operating voltage and adjust R15 until a rushing noise is heard in the speaker. Do not advance R15 beyond this point as the sensitivity of the receiver will decrease. Next, tune in a weak signal from another ham station (or from a signal generator) and tune L7 for a peak response. Chances are that when the peak is reached, the detector will stop oscillating. If this happens, advance R15 until the hiss returns. If it does not, detune L7 slightly until a compromise is reached (L7 usually loads the detector somewhat when it is tuned to the operating frequency). Alternatively, a 1000-ohm swamping resistor can be connected across L7 to reduce its effect on the detector. Trimmer C20 is used to set the tuning range of C22. The turns of L8 can be spread or compressed for additional frequency adjustment. The receiver should tune the entire 4-MHz of the 2-meter band, or nearly so.

A No. 49 pilot lamp makes a suitable dummy load for visual tune-up of the transmitter, though somewhat reactive at 144 MHz. First, determine that the oscillator, Q1, is operating by coupling a wavemeter (or grid-dip meter in the diode-detector position) to L1 and look for an indication of output. Adjust the slug in L1 for maximum output, then turn the transmitter on and off a few times to make sure the crystal always kicks in. If not, detune L1 slightly toward the high-frequency side of resonance until the oscillator does start each time. Next, peak L2, C10, C12 and C15 for maximum indication on the bulb. There will be some interaction between the circuits, so the foregoing steps should be repeated a few times to assure maximum output. Final adjustments should be made with the antenna connected, and with an SWR indicator in the line.[2]

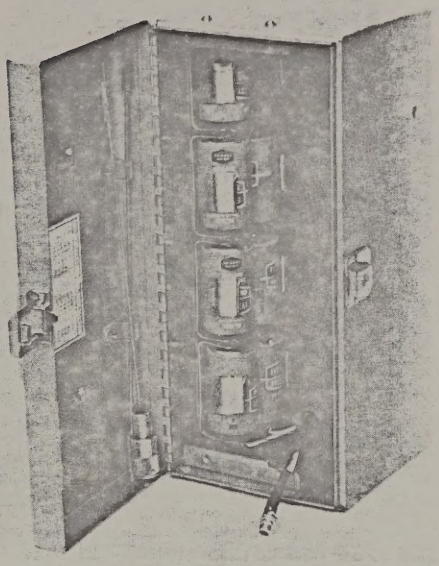


Fig. 10-59 — Eight size D cells are series connected to provide 12 volts. They are mounted in Keystone holders on the back wall of the bond box. The 1/4-inch diameter hole in the front of the cabinet (upper right of photo) permits final calibration of the receiver (C20) after the installation is completed. The hole is opposite the shaft of C20.

[2] A highly sensitive SWR indicator is needed at this power level. One of the Monimatch indicators with a 4-inch or longer line (air-dielectric element type) can provide full-scale readings if a 100-μA meter is installed. Alternatively, see *QST* August, 1967 for a low-power bridge. Also, see the "Monimatch Mark II," *QST*, February, 1957.

A QRP CONSOLE

It's handy to keep the station equipment neat and orderly, especially during portable or emergency operation. This QRP console is a fitting mate for the transceiver shown earlier in this chapter, and permits matching the transceiver output to almost any load, reactive or resistive in nature. The tuner portion will look into end-fed random or resonant wires, coax-fed antennas, or into antennas that use balanced feeders. Ideally, the antenna would be cut to a resonant length, but even with nonresonant antennas this tuner will disguise whatever SWR is present to give the transceiver the 50-ohm load it is designed to look into.

The Circuit

As shown in Fig. 2, the transceiver connects to J1 at low impedance (50 ohms). An SWR bridge is permanently in the low-impedance part of the line, and permits the operator to adjust the antenna tuner for zero reflected power, which will correspond to a 50-ohm termination at the output port of the bridge (junction of C6 and L1). The forward-power reading can be used when tuning up the transmitter portion of the transceiver.

The tuner consists of a pi-section tuned circuit whose inductor is tapped at 10 places to permit a variety of matching conditions on 80 and 40